# Occultation Recording Assembly Implementation

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*The Mariner Mars 1971 Occultation Experiment, in order to expedite data reduction and analysis, required real-time digital tape recordings of DSS 14's open loop receiver signal and nonreal-time digital tape conversion of the analog tapes (of the open loop receivers) produced by the overseas stations DSS 41 and DSS 62. This article presents a description of the implementation of the two Occultation Recording Assemblies, which were used to satisfy these requirements.*

## I. Introduction

The Occultation Recording Assemblies are two new additions to the DSN. One of the assemblies was installed at DSS 14 on September 1, 1971 and the other at CTA 21 on October 1, 1971 for the *Mariner* Mars 1971 Occultation Experiment. The purpose of the Occultation Recording Assemblies is to digitize and time correlate *Mariner 9*'s radio signal as it is transmitted through the Martian atmosphere, in order to determine the shape and atmospheric characteristics of the planet.

### A. DSS 14 Version

The assembly at DSS 14 performs a 6-bit digitization, at a 30,000- or 40,000-sample per second rate (dependent on the bandwidth of the open loop receiver), of the real-time analog signal from the station's open loop receiver (see Fig. 1). The 30- or 40-kHz tone is supplied by the open loop receiver. The assembly also formats, time tags, and records the digital data onto a 9-track digital magnetic tape as shown in Fig. 2.

The magnetic tape format contains 4096 data conversions per tape record, header information, and a time tag from day of year to a microsecond resolution. The time recorded is the time at which the first data point of that record was obtained. The time information from day of year to seconds is obtained from the Frequency and Timing Subsystem (FTS). The remaining time data is generated within the Occultation Assembly.

The recording process can go on indefinitely, since there are two digital magnetic tape recorders. The recorded digital tapes are subsequently analyzed at the SFOF to determine the shape of the Martian planet and the characteristics of its atmosphere.

### B. CTA 21 Version

The Occultation Assembly at CTA 21 performs identically to the system at DSS 14, except that it receives its analog signal from analog tapes shipped from the overseas stations DSS 41 and DSS 62 (see Fig. 3). Also, the time resolution is from day of year to 1 millisecond.

One track of the analog tape provides the open loop receiver signal linearly mixed with a reference tone and another track contains a NASA time of day code. The Occultation Assembly separates the two mixed signals and uses the tone as a clock for the analog-to-digital converter (ADC) to digitize the open loop signal. NASA time is used to time-tag the data.

## II. Occultation Recording Assembly Specification

The specifications for the Occultation Recording Assembly are as follows:

(1) Input: ±10-V analog voltage signal.

(2) Output: 9-track digital magnetic tape.

(3) Analog-to-digital (A/D) conversion rate: 30,000 or 40,000 samples per second.

(4) Number of bits per A/D conversion: 6 bits.

(5) Conversion digital output code:
Positive input voltage, binary.
Negative input voltage, 2's complement.

(6) Time of day resolution:
Day of year to 1 microsecond (DSS 14).
Day of year to 1 millisecond (CTA 21).

(7) Recording Time: Unlimited.

## III. Occultation Assembly Hardware

### A. DSS 14 Occultation Recording Assembly Hardware Description

The Occultation Recording Assembly at DSS 14 consists of a single standard DSIF equipment rack and a set of dual 9-track digital magnetic tape recorders. The equipment rack contains the following equipment:

(1) Amplifiers: Hewlett Packard, Models 467A and 465A.

(2) Analog-to-digital converter (ADC): Adage Co., Model VT7-AB/SA4-3580.

(3) Interface electronics: JPL supplied.

(4) Occultation central processing unit (CPU): Interdata, Model 4 computer.

(5) Dual 9-track digital magnetic tape transports: Xerox Data System, Model 731.

(6) Phase shifter: Merrimac, Model R1.0.

(7) Power supplies: Lambda, Models LM-B-12, LM-C-12, and LM-E-5.

(8) Power panel: JPL supplied.

#### *1. Amplifiers*

*a. HP467A.* The HP467A amplifier/power supply is a non-inverting amplifier with a fixed or variable gain setting of up to 10. It is used as a buffer amplifier between the open loop receiver and the ADC. It is also used as a variable voltage power supply to calibrate the Occultation Assembly.

*b. HP465A.* The HP465A amplifier is used as a buffer amplifier for the 1-MHz timing signal received from the FTS. This signal is used as a clock to generate time of day, within the assembly, from one-tenth of a second to one microsecond.

***2. Analog-to-digital converter.*** The ADC converts the open loop receiver analog signal into the six-bit digital format. These digital data are sent to the computer via the interface electronics. The ADC is a single-channel converter with an input voltage range of ±10 volts. It contains a sample and hold amplifier with a 10-nanosecond aperture time.

***3. Interface electronics.*** The interface electronics is composed of JPL high-reliability modules and military-approved SN5400-series digital integrated circuits. Its purpose is to interface the ADC and time data to the CPU as well as to provide timing functions. The interface electronics consist of 8 card files and one integrated circuit card (controller) which contains approximately 150 integrated circuits (IC).

The function of the card files and IC card is described below:

(1) *Card file 1, 24-bit register.* The 24-bit register collects four 6-bit data samples from the ADC and then transfers the data to the computer via the IC controller.

(2) *Card file 2, four-step sequencer.* The four-step sequencer receives an end of conversion pulse from the ADC, and properly sequences each 6 bits of data into the 24-bit register. When four of these 6-bit samples have been collected, it alerts the IC controller that the data are ready for transfer. The four-step sequencer also counts the number of conversions that have been performed and provides a READ pulse to the time register when time of day should be updated.

(3) *Card files 3, 4, and 5, time register, and transfer gates.* These three card files make up the 54-bit time register and transfer gates. The time data are stored in this register upon initiation of a READ pulse from the four-step sequencer. These data are transferred to the computer via the IC controller.

(4) *Card file 6, low-order time counter.* This counter is a six-stage BCD counter, whose clock is a 1-MHz signal from the FTS. It produces time of day from one-tenth of a second to 1 microsecond.

(5) *Card file 7, negative to positive converter.* This card file translates the 30 FTS time data bit logical voltages to +12 V and ground from −12 V and ground.

(6) *Card file 8, input timing circuits.* This card file squares up the 1-MHz signal from the FTS and the 30- or 40-kHz tone signal from the open loop receiver to produce the timing clock for the low-order time counter and the conversion pulse signal for the ADC, respectively. It also performs some of the system timing requirements.

(7) *IC controller card.* The controller card provides the input/output interface between the above-mentioned electronics and the computer. It transfers 6 bits of data at a time to the computer via the selector channel and 12 bits of time data at a time via the multiplexer channel, upon request from the computer. It also provides the start/stop commands to the system.

***4. Phase shifter.*** The phase shifter is used to synchronize the 1-MHz signal from the FTS, to produce coherent time of day in the low-order time counter.

***5. Occultation central processing unit (CPU).*** The Occultation CPU is an Interdata Model 4 computer with the following optional equipment:

(1) Two high-speed direct memory channels (selector channels).

(2) Magnetic tape controller and selector channel.

(3) Sixteen-line interrupt module.

(4) Four 16-bit programmable input/output multiplexer channels.

The computer is microprogrammable and has a full instruction set which is an emulation of a subset of the IBM 360/20 instruction set.

The computer is used as a data collector and formatter and controls the sequence of operations. The computer is programmed so that after 4096 data samples and time of day are collected in part of its memory, the incoming data are transferred to an alternate memory section. The collected data are then outputted to the digital recorder. The output data rate is faster than the input data rate to insure that overflow does not occur. When the alternate half of the memory is filled with data, they are outputted and incoming data are stored in the first half of the memory. The program detects when the first recorded tape is filled and automatically switches to the second tape recorder without loss of data flow. This allows for an unlimited recording time.

***6. Dual 9-track digital magnetic tape transport.*** The dual-tape transports are 9-track, 75-inch-per-second machines with a recording density of 800 bits per inch. The tapes produced are 9-track IBM-compatible.

***7. Power supplies.*** The power supplies provide the voltages for the interface electronics.

***8. Power panel.*** The power panel distributes the three-phase ac power to the occultation rack.

### B. CTA 21 Occultation Recording Assembly Hardware Description

The Occultation Recording Equipment at CTA 21 is identical to the DSS 14 system except for the front end, since its analog signal is supplied by an analog tape recorder. The equipment, in addition to that listed under the DSS 14 system, is as follows:

(1) Analog recorder: Ampex, Model FR 2000.

(2) Tunable low-pass filter: EMR, Model 4190.

(3) Band-pass filters: Genisco, Model GF-52143-1 (30 kHz) and Model GF-52143-2 (40 kHz).

(4) Time-code translator: Astrodata, Model 5220.

(5) Tape search and control unit: Astrodata, Model 5224.

***1. Analog recorder.*** The FR 2000 analog recorder is a high-performance transport with low flutter and dynamic skew. It is a seven-track recorder. One of its tape tracks contains the time of day NASA code and another contains the recorded open loop receiver signal mixed with the tone signal.

***2. Tunable low-pass filter.*** The mixed analog signal from the analog recorder is sent to the tunable low-pass filter, which removes the tone from the signal, producing the open loop receiver signal. The open loop receiver signal is then fed to the ADC for digital conversion.

3. ***Band-pass filters.*** The 30- or 40-kHz band-pass filter (choice depends on tone frequency) separates the tone from the analog recorder's mixed signal. The separated 30- or 40-kHz signal is used as the conversion pulse for the ADC.

4. ***Time code translator.*** One track of the analog tape contains the NASA time code. This signal provides an indication of tape position. During playback and search, the time signal is fed to the time code translator, which converts this signal to a parallel 42-bit digital BCD time code. This BCD time code is time of day from day of year to a millisecond, which is transferred to the time register upon command.

5. ***Tape search and control unit.*** The tape search and control unit automatically compares the BCD time output from the time code translator with the preset start/stop recording times on its front panel. The result of this comparison determines the commands sent to the tape motion electronics of the analog recorder, e.g., rewind, forward, stop, etc. This automatically converts only the desired section of the analog tape into digital tape.

## IV. Occultation Software

The purpose of the *Mariner* Mars 1971 Occultation Recording Software is to provide a means for operating and testing the Occultation hardware. The Occultation software consists of two subprograms: a test program and the operational program.

The test program checks to see that the data and time information flow correctly through the system and onto the digital magnetic tape. If not correct, it indicates where there is a problem. Specifically, the test program reads ADC samples, compares them to an operator-selected pattern, and prints any anomalies onto the system's teletypewriter. It also reads and prints GMT onto the teletypewriter and writes and confirms a magnetic tape record.

The operational program performs the data collecting, data formatting, and system transfers that are required. The program accepts 6-bit ADC samples, time tags the first sample of each record, includes header information, and outputs the records of 4096 samples onto 9-track digital magnetic tape (the generated tapes are compatible with the IBM 360 in the SFOF). The operational program also detects the end of tape and automatically switches the digital recording to the waiting tape recorder without loss of data flow.

## V. Future Configuration of the Occultation Recording Assembly at CTA 21

The present configuration of the CTA 21 Occultation Recording Assembly includes dedicated computer and digital magnetic tape recorders. This equipment is presently being borrowed from the Data Decoder Assembly (DDA) equipment. Once the DDA becomes operational at CTA 21, the Occultation Recording Assembly will timeshare the DDA's computer and digital magnetic tape recorders.

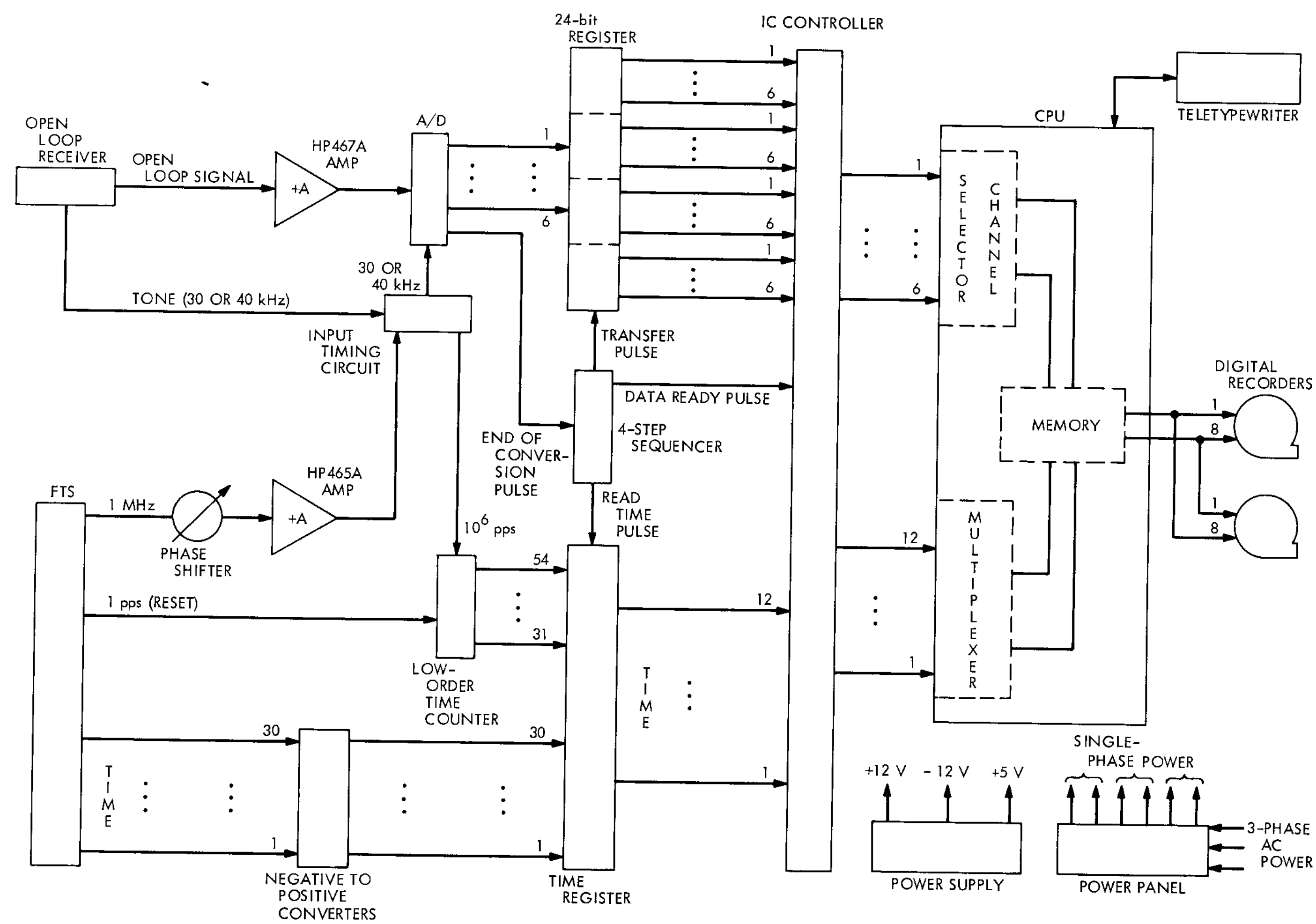


**Fig. 1. DSS 14 occultation recording assembly**

| CODE | MEANING |
|---|---|
| $p'$ | LONGITUDINAL EVEN PARITY BIT |
| W | DATA SAMPLE BIT |
| S | STATION CODE<br>10 - DSS 14<br>01 - DSS 41<br>11 - DSS 62 |
| DS | DATA SOURCE<br>0 - ANALOG<br>1 - DIGITAL |
| $D_1 - D_{10}$ | BCD DAY BITS |
| $H_1 - H_6$ | BCD HOUR BITS |
| $M_1 - M_7$ | BCD MINUTE BITS |
| $S_1 - S_7$ | BCD SECOND BITS |
| $M_1 - M_{12}$ | BCD MILLISECOND BITS |
| $\mu_1 - \mu_{12}$ | BCD MICROSECOND BITS |
| $p$ | ODD PARITY BIT |

START OF FIRST RECORD

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $p$ | 0 | 0 | 0 | 0 | S | S | 1 | DS | HEADER |
| $p$ | 0 | 0 | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_6$ | |
| $p$ | 0 | 0 | $D_7$ | $D_8$ | $D_9$ | $D_{10}$ | $H_1$ | $H_2$ | |
| $p$ | 0 | 0 | $H_3$ | $H_4$ | $H_5$ | $H_6$ | $M_1$ | $M_2$ | |
| $p$ | 0 | 0 | $M_3$ | $M_4$ | $M_5$ | $M_6$ | $M_7$ | $S_1$ | |
| $p$ | 0 | 0 | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | $S_7$ | TIME OF DAY FOR FIRST DATA WORD IN RECORD |
| $p$ | 0 | 0 | $M_1$ | $M_2$ | $M_3$ | $M_4$ | $M_5$ | $M_6$ | |
| $p$ | 0 | 0 | $M_7$ | $M_8$ | $M_9$ | $M_{10}$ | $M_{11}$ | $M_{12}$ | |
| $p$ | 0 | 0 | $\mu_1$ | $\mu_2$ | $\mu_3$ | $\mu_4$ | $\mu_5$ | $\mu_6$ | |
| $p$ | 0 | 0 | $\mu_7$ | $\mu_8$ | $\mu_9$ | $\mu_{10}$ | $\mu_{11}$ | $\mu_{12}$ | |
| $p$ | 0 | 0 | $W_5$ | $W_4$ | $W_3$ | $W_2$ | $W_1$ | $W_0$ | 1ST DATA WORD |
| $p$ | 0 | 0 | $W_5$ | $W_4$ | $W_3$ | $W_2$ | $W_1$ | $W_0$ | 2ND DATA WORD |
| $p$ | 0 | 0 | $W_5$ | $W_4$ | $W_3$ | $W_2$ | $W_1$ | $W_0$ | • |
| | | | | | | | | | • |
| | | | | | | | | | • |
| $p$ | 0 | 0 | $W_5$ | $W_4$ | $W_3$ | $W_2$ | $W_1$ | $W_0$ | 4095TH DATA WORD |
| $p$ | 0 | 0 | $W_5$ | $W_4$ | $W_3$ | $W_2$ | $W_1$ | $W_0$ | 4096TH DATA WORD |
| $p'$ | $p'$ | $p'$ | $p'$ | $p'$ | $p'$ | $p'$ | $p'$ | $p'$ | |
| | | | | | | | | | INTERRECORD GAP |
| $p$ | 0 | 0 | 0 | 0 | S | S | 1 | DS | START OF SECOND RECORD |
| $p$ | 0 | 0 | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_6$ | |

**Fig. 2. Tape record format**

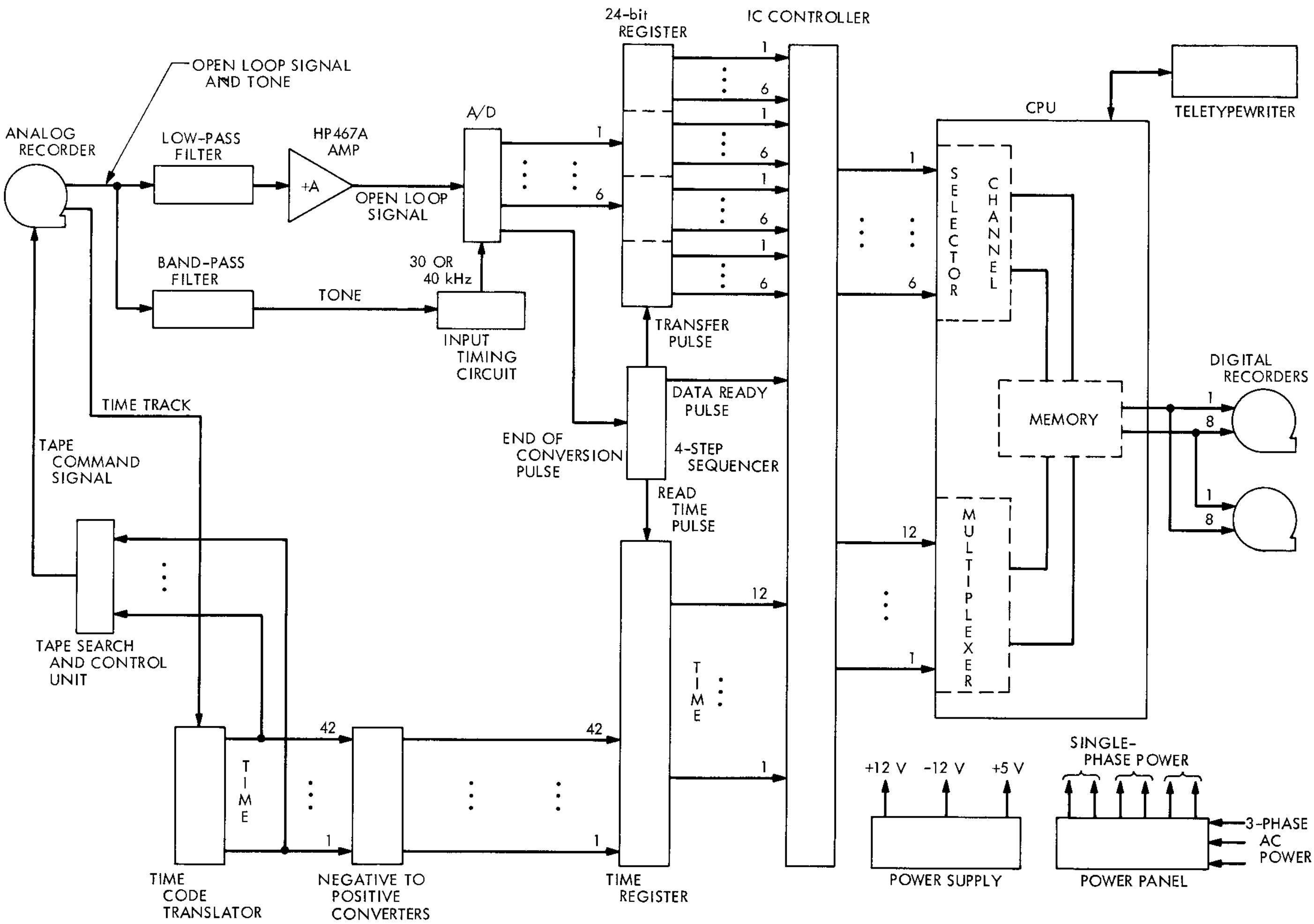


**Fig. 3. CTA 21 occultation recording assembly**